Proceedings: Guidelines For Regenerating Appalachian Hardwood Stands

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EFFECTS OF FIRE ON NATURAL REGENERATION IN THE APPALACHIAN MOUNTAINS

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ABSTRACT

Research indicates that prescribed fire may have more potential in regenerating Appalachian hardwoods than demonstrated by current use. Studies show that repeated low-intensity fires increase oak advance regeneration, suggesting that a series of burns prior to harvest could result in a predominantly oak stand. Single pre- or post-harvest burns have little affect on species composition of the advance regeneration. Following harvest, winter burns on cove sites have stimulated the establishment of yellow-poplar from seed stored in the duff. Summer broadcast burns, used in conjunction with the proper time to fell residuals and planting, are currently used successfully to regenerate mixed pine-hardwood stands. Recent studies indicate that prescribed fire can be used in the steep terrain of the Appalachians with minimal adverse environmental effects if properly conducted. More research is needed to completely document the role that fire might play in regenerating Appalachian hardwoods and the effects that increased use of fire may have on the environment.

Introduction

Probably less is known concerning fire effects in the Eastern hardwood forests than in any other timber type. This statement is not meant to imply that fire has had a small ecological role in this region. Ecologists have long recognized that upland oak stands in pre-Colonial America depended upon recurring wildfires for their continued existence (Cooper 1961). Other species, like yellow-poplar, developed adaptations that enabled them to successfully regenerate on fire-prepared seedbeds.

Prescribed fire is seldom used as a forest management tool in the Appalachians. However, some research indicates that it may have potential benefits when cautiously used in certain forest cover types of the region. More research is needed before specific recommendations for its use can be made.

The purpose of this paper is to discuss the current state of knowledge concerning effects of fire on natural hardwood regeneration in the Appalachian Mountains and to briefly review environmental effects of prescribed fire in steep terrain. Since relatively little information is available concerning fire in this region, sources dealing with studies beyond the Appalachian boundaries will be cited where necessary.

Effects of Fire on Hardwoods

Most of the information concerning effects of fire on hardwoods has come from studies of hardwood control in pine stands of the Coastal Plain and Piedmont. These studies have shown that the size, but not the number, of understory hardwoods is controlled by fire. Low-intensity prescribed burns are effective in top-killing most hardwood stems up to a 3-inch ground diameter (Langdon 1981). However, root stocks of top-killed hardwoods will generally produce multiple sprouts.

Hardwood sprouting after top-kill by frequent fires is extremely persistent, although the ability to continually resprout varies by species. Oaks tend to be the most resistant to mortality from periodic fires. Frequent burning (annual or biennial) increases herbaceous vegetation. Therefore, various combinations of fire frequency and timing can affect the composition and structure of understory vegetation, including the advance regeneration pool of hardwood stems.

Forty years of understory burning on the Santee fire plots in the Coastal Plain of South Carolina illustrate the effects of prescribed fire on the hardwood understory in mature loblolly pine stands (Waldrop et al. 1987). Understory growth was vigorous and composed of all size classes of hardwoods up to 20 in dbh on control plots which had received no burning for 80 years. On plots burned periodically (about every 5 years), the great majority of hardwood stems are less than 1 inch dbh. The only hardwood stems greater than 6 inches after 40 years of burning were those that were large enough to survive the early fires. These periodic fires were frequent enough to top-kill most of the hardwood stems less than 2 inches dbh, but their root systems survived and produced multiple sprouts. Burns of 5 year intervals were evidently not frequent enough to promote oak regeneration. All species survived, but oaks decreased in abundance, possibly due to shading from shrubs and other understory vegetation.

Annual winter burning of the Santee fire plots produced the largest numbers of stems less than 1 inch dbh, but nearly all of these stems were less than 3 feet tall. These cool dormant season burns caused little mortality of hardwood root stocks. Sprouting of oaks was increased over controls, but the gain was masked by a seven-fold increase in the number of sweetgum sprouts.

Biennial summer burning produced the most positive response in terms of promoting oak advance regeneration. Growing season burns were of sufficient intensity to kill hardwood root stocks. After a period of 6 to 8 years (4 to 5 biennial burns) the relative abundance of oaks began to increase because of their superior resistance to mortality from fire. After 14 biennial summer burns, oak survival was over 50 percent as compared to less than 20 percent for other hardwoods.

Only annual summer burning was capable of complete elimination of understory hardwoods. Burning in the summer top-kills small hardwoods when most of the carbohydrate reserves are in the tops of the plants and sprouting vigor is low. A series of annual summer burns gradually killed the root stocks of all understory hardwoods, including the oaks.

Types of Prescribed Fires

Prescribed fires are generally of one of three types. Head fires burn with the wind or upslope. They are of relatively high intensity and move through fuels at a relatively high rate of speed. Head fires are often ignited in strips (called strip headfires) to speed the burning process and to provide the desired intensity. Fire intensity increases as the rear of a previously ignited strip merges with the advancing front of a subsequent strip.

Back fires back into the wind or burn down slope. They burn with lower flame heights, i.e., lower intensity, and move through the stand at slower speeds than head fires. Back fires, because of their lower intensity and slower speeds, are more easily controlled.

Flank fires are sometimes used to supplement other burning techniques. They are often used to speed the process of burning with backfires. Flank fires are set perpendicular to backfires. Where flank fires merge, fire intensity increases.

Fire Intensity, Residence Time, and Fire Severity

Fireline intensity is defined as the heat output of a unit length of fire front per unit of time (Deeming et al. 1977). Fireline intensity is directly related to flame length, a readily observable feature of a fire. It is important in prescribed burning because intensity is a major factor determining mortality or damage to both understory and overstory hardwoods. As trees grow larger they become more resistant to fire because their crowns are above the heat of the flames and thicker bark provides greater insulation to the cambium. Thus, hotter fires are necessary to kill or damage larger trees.

In addition to fire intensity, the duration of exposure or residence time is an important consideration when planning a prescribed fire. Protoplasm can be instantly killed at a temperature of 147° F, but also can be killed by prolonged exposures to lower temperatures (Nelson 1952). Backing fires of low intensity can be lethal to small stems because their slow speeds enable lethal cambium temperatures to be reached just above the ground line. Conversely, where understory stems are larger and have thicker bark, headfires are likely to be more lethal than backfires because of damage to the crowns.

It is important to appreciate the difference between fire intensity and severity. Fire severity is defined as the condition of the ground surface after the burn (Wells et al. 1979). Fire intensity relates to the rate at which an on-going fire is producing thermal energy. The two terms are not necessarily closely related, although they may be. For example, a burn that consumes all the organic layer and alters mineral soil structure and color over most of the burned area would be classified as a severe burn. A high intensity fire in heavy fuels that burns when the soil and forest floor are moist would leave a large amount of residual forest floor and not alter soil structure and color. Thus, in this example, a high intensity fire would be classified as light severity.

Environmental Effects of Fire in the Appalachians

By necessity, we will confine our remarks concerning fire effects on the environment to the Southern Appalachians and upper Piedmont. Effects of burning on the soil vary. High intensity wildfires burning under droughty conditions may expose the soil to erosion and cause heat damage to soil physical properties (Wells et al. 1979). Conversely, intense broadcast burns in the Southern Appalachians under proper fuel and soil moisture conditions do not necessarily result in increased erosion or reduced infiltration rates (Van Lear and Danielovich 1988). To minimize soil damage and off-site effects of broadcast burns in steep terrain, it is extremely important to conduct the burns so that a residual forest floor will be left to protect the site. To accomplish this, the lower portion of the forest floor and the mineral soil must be damp.

Low intensity burns normally consume only a portion of the forest floor and have little impact on soil properties or water quality. Brender and Cooper (1968) found no evidence of soil movement after a single prescribed fire in the Piedmont of Georgia. Douglass and Van Lear (1983) noted that two low-intensity understory burns in mature loblolly pine plantations had no adverse effect on ephemeral stream sediment or nutrient concentrations in the South Carolina Piedmont. Adverse impacts on soil and water from infrequent low intensity burns are not generally detected because of the protective effect of the residual forest floor and because hydrologic functioning and soil processes are maintained at normal levels. Research is needed to evaluate the effects of high intensity fires on nutrient pools and biological processes in these mountain ecosystems.

There are few long-term studies of effects of prescribed burning on soil chemical properties in the Southern Appalachians. On the Highland Rim in eastern Tennessee, Thor and Nichols (1974) found no significant effect of annual or periodic winter burning over a 7-year period on soil pH or available phosphorus. Available potassium tended to be higher in unburned stands, perhaps because potassium, a highly mobile element, may have been leached or taken up by vegetation more readily on burned plots. On the Coastal Plain, other long-term burning studies have shown that low-intensity prescribed fires have little adverse impact on soil fertility and may improve such properties as available phosphorus and organic matter content (McKee 1982).

In the southeastern United States, prescribed burning is often used to improve habitat for game and non-game species. Reports which summarize these numerous studies were given by Harlow and Van Lear (1981, 1987). Increased sprouting of hardwoods and other browse after burning has been commonly reported. The protein and phosphorus content of browse, as well as palatability, are improved following burning (Stransky and Harlow 1981), but these improvements are short lived. Fruit production of understory plants, such as gallberry, huckleberry, and blueberry, may be reduced if burning cycles are less than 3 years (Stransky and Halls 1980).

The effect of prescribed fire on wildlife depends on the particular species of wildlife, fire frequency, fire intensity, season, and fuel types. Interrelationships among these factors are complex. In addition, habitat requirements for some wildlife species are not well defined. For these reasons, it is often difficult to predict effects of prescribed fire on wildlife in general. Programs of burning that favor certain species may create conditions unfavorable to others. A close working relationship between foresters and wildlife managers, both of whom must understand fire effects, is necessary to design fire prescriptions that will benefit those wildlife species favored in management.

Air pollution must be a major concern when a prescribed burning program is considered. Smoke is rapidly dispersed high into the atmosphere and causes few problems when burning is conducted under appropriate atmospheric conditions. However, when smoke settles on highways or impacts other sensitive areas, accidents and lawsuits may result. Besides its effects on visibility, smoke contains several compounds known to affect human health (McMahon 1985). Smoke management guidelines have been developed to reduce the atmospheric impacts of prescribed fire (USDA Forest Service 1976). Smoke management will be a major concern if fire is used more frequently in the Appalachians, where topography and population distribution dictate that smoke be effectively dispersed.

Burning to Enhance Natural Regeneration

Research on the use of fire for hardwood regeneration is limited, which is partially due to foresters' concern of damaging stem quality in high value stands. However, much of the information on bole damage comes from early studies of wildfires (Abell 1932; Nelson et al. 1933), which may not be applicable to lower intensity prescribed fires. Sanders et al. (1987) found that low intensity backing fires in mature hardwood stands during the winter had little adverse effect on crop trees.

The potential for damage to boles of thin-barked hardwoods by high intensity fires is readily evident from the numerous fire scars seen in many Appalachian stands. However, the role of low-intensity prescribed fires in stand management and the use of higher intensity broadcast burning for promoting quality coppice regeneration deserves greater attention from fire research. Researchers are now beginning to realize that hardwood species evolved under a regime of frequent burning and that prescribed fire may be a useful tool in hardwood management (Van Lear and Waldrop 1987). At present, research results on the use of fire for hardwood regeneration are limited to the oak-hickory, cove hardwood, and pine-hardwood cover types.

Oak - Hickory Cover Type

The oak-hickory type is widespread in the eastern United States, covering over 114 million acres of commercial forest land (Burns 1983). However, regeneration of this type has been difficult. Today it is recognized that even-aged management of oak types is necessary and that regeneration can be accomplished by similar techniques to those used for other intolerant types (McGee 1975). Clearcutting and shelterwood cutting are acceptable regeneration techniques but advance regeneration of oaks is required to compete with other species in the understory (Roach and Gingrich 1968). Sufficient quantities of adequately sized advance oak regeneration to comprise a major component of the regenerated stand are often difficult to obtain. Sander (1972) suggests that a minimum of 435 oak stems per acre over 4.5 feet tall is required for successful regeneration. One theory, yet to be proven, for the failure to successfully regenerate oak stands is that the exclusion of fire or other disturbances has altered the ecology of these stands to the detriment of advance oak regeneration (Van Lear and Johnson 1983).

Some research lends support to this theory. Two studies conducted in the Northeast (Swan 1970; Niering et al. 1970) and one in the southern Coastal Plain (Langdon 1981) found that seedlings of oaks are less susceptible to root kill by fire than competitors of other species, thus giving the oaks an ecological advantage. This fact would indicate that periodic burning can play a major role in promoting advance oak regeneration. Waldrop et al. (1987) reported that survival of oaks was greater than for competing species after 4 to 5 biennial summer burns. Periodic (2 or more years) fires may be the key to oaks predominating over their associates. However, the exact combination of season and frequency of burning to promote advance oak regeneration in the Appalachians has not been determined.

Several studies support the theory that multiple prescribed burns are necessary to promote advance oak regeneration prior to harvest. Thor and Nichols (1974) found that advance regeneration of oaks in central Tennessee was doubled by both annual (for 6 years) and periodic (2 burns, 5 years apart) prescribed fires. Carvell and Tryon (1961) reported large increases in advanced oak regeneration in West Virginia where stands had been burned several times over a 20 year period. Keetch (1944) found that oak sprouting was stimulated by a single prescribed fire and was maintained by three successive fires.

A single fire has little effect on species composition in the understory and may provide conditions more favorable for light-seeded species and those which depend on seed stored in the forest floor (Loftis 1978). Johnson (1974) reported that a spring fire in a 102-year-old northern red oak stand failed to increase oak abundance in the understory. The fire also failed to control competing vegetation and killed 58 percent of the existing seedlings. Wendel and Smith (1986) reported no increase of advance oak regeneration after a single spring burn in a central Appalachian oak-hickory stand. The fire caused severe damage to the boles of overstory trees and increased competing vegetation. Teuke and Van Lear (1982) found only slight benefits to oak regeneration after single winter burns in western South Carolina and northeastern Georgia.

Two studies have reported effects of post-harvest prescribed burns on oak regeneration. McGee (1979) noted little change in species composition after a single burn in 5- to 6-year-old stands on the Cumberland Plateau in northern Alabama. Sprouting of red maple was increased, so the relative dominance of oaks decreased. Waldrop et al. (1985) used a spring burn in a 3-year-old hardwood stand on the Cumberland Plateau in East Tennessee. Burning caused little change in species composition. Both burned and unburned plots were dominated by oaks but oak abundance did not increase relative to other species.

With both studies of post-harvest burning, only a single burn was attempted. If the resistance of oaks to root-kill that was demonstrated on the Santee Fire Plots (Waldrop et al. 1987) holds true for oaks in the Appalachians, several periodic prescribed burns may have resulted in increased oak abundance. Repeated post-harvest burns offer the advantage of maintaining browse for deer over a number of years, but their effects on oak regeneration have not been studied.

With any prescribed burning operation, the potential for success must be considered before making the decision to risk the use of fire. When the objective of burning is to increase oak sprouting, a large portion of the understory must be oaks that are small enough to be top-killed by fire.

Hardwoods over 3 inches dbh generally survive low-intensity prescribed fires. In many older and undisturbed stands, smaller oak stems have been shaded out of the understory. In this case, burning may not be beneficial or should be postponed until after a shelterwood cut allows oak seedlings to become better established.

Cove Hardwoods

The task of regenerating oaks, particularly northern red oak, is more difficult on cove sites than on upland sites. On moist and fertile cove sites, understory vegetation competes vigorously with oak seedlings and usually overtops them. Therefore, advance regeneration of desired species is required. In addition, some control of the subcanopy and midstory is necessary to favor advance regeneration (Loftis 1980).

Recent publications suggest that fire exclusion from cove sites has created environmental conditions unsuitable to oak regeneration (McGee 1979; Russell 1979). However, research on the use of periodic fire for regenerating cove hardwoods is lacking. Two current studies by Loftis (1978; 1980) will provide more information on the use of fire in cove sites. One study will examine the effects of periodic fire on understory species composition, while the other will examine the effects of periodic fire and various levels of basal area removal on the development of advance oak regeneration.

While fire has not been proven to promote oak regeneration on cove sites, it has been successful for regenerating yellow-poplar. This species has adapted to fire disturbance by developing light seed which is disseminated by wind and gravity and germinates rapidly in fire prepared-seedbeds. Yellow-poplar seeds also remain viable in the duff for approximately 10 years and then germinate rapidly after a fire (McCarthy 1933). Sims (1932) found that yellow-poplar seedlings were more numerous in clearcut and unharvested stands that had been burned as compared to similar stands that had not been burned. Shearin et al. (1972) noted that the number and height of yellow-poplar seedlings were significantly increased on Piedmont sites three growing seasons after a low intensity winter burn on a clearcut area. Viable seeds stored in the duff before burning accounted for the large number of seedlings after burning.

Pine-Hardwood Mixtures

While forest management is traditionally aimed at pure pine or mixed hardwood stands, a new site preparation technique for promoting pine-hardwood mixtures is gaining widespread acceptance in the Southern Appalachians. This technique, commonly described as "fell and burn", relies heavily on the use of broadcast burning. Detailed descriptions of the fell and burn technique were given by Abercrombie and Sims (1986), Phillips and Abercrombie (1987), and Van Lear and Waldrop (1987) and are summarized here.

The fell and burn site preparation technique consists of two steps. After clearcutting hardwood or pine-hardwood stands, generally on medium quality sites, residual stems over 6 feet tall are felled by chainsaw crews. Felling is conducted during the early spring following full leaf development. Timing is critical because carbohydrate reserves in the roots are at their lowest after leaf development and resulting sprouts will be of reduced vigor. Also, the presence of leaves will speed the drying of small twigs and serve as fuel for a broadcast burn, which is the second step of the technique. Burning is conducted in mid-July to early August within 24 to 48 hours after a soaking rain, ensuring that a residual forest floor and root mat will provide protection against erosion. Improved shortleaf or loblolly pines are planted the following winter.

While this technique does not reduce the number of hardwood sprouts that compete with planted pines, it does reduce sprout vigor enough to allow pines to become established and grow (Danielovich et al. 1987). Pine survival is generally over 90 percent the first year after planting and over 75 percent after 4 years (Phillips and Abercrombie 1987). In three stands planted with shortleaf pine, oaks were numerous but much shorter than pines. Oaks were generally less than 6 feet tall while pines averaged over 8.5 feet.

Summer broadcast burning is probably the more beneficial of the two steps in this site preparation technique. Sprouts that developed after chainsaw felling are top-killed and new sprouts are less vigorous. Burning removes over 65 percent of the woody fuels less than 3 inches in diameter (Sanders and Van Lear 1987), making the site more accessible for planting. After planting, the black surface makes green seedlings more visible, thus ensuring a better job of planting. The fire also kills aboveground buds on hardwood stumps, forcing new sprouts to originate from below ground ensuring that they are better anchored and of better form.

The fell and burn technique has proven valuable in producing pine-hardwood stands in the Southern Appalachians. It is an inexpensive technique that increases diversity by adding a pine component, improves habitat for deer and turkey, and is well accepted by the general public. However, many questions remain unanswered. At present, there are no stands regenerated by this technique older than 7 years. Therefore, future growth and yield and the need for intermediate treatments is yet to be determined. Also, the fell and burn technique has not been attempted outside of the Southern Appalachians so problems specific to other areas are unknown.

Conclusions

Prescribed fire is an increasingly used forest management tool in the southern Appalachians. Studies suggest the fire could be an important tool in regenerating hardwoods and have potential benefits when applied to certain forest cover types. Some general thoughts concerning prescribed fire and Appalachian hardwoods are:

1. Single preharvest or postharvest fires have little effect on species composition of advanced regeneration.

2. Repeat low intensity fires increase oak advanced regeneration as well as increase top-kill of most hardwood stems up to a 3-inch ground diameter.

3. Root stocks of top-killed hardwoods produce multiple sprouts.

4. Fire kills above ground buds on hardwood stumps forcing new sprouts to originate from below ground resulting in sprouts that are of better form and low-origin.

5. Frequent burnings (annual or biennal) continues to stimulate root stock sprouting of certain species such as oaks. Herbaceous vegetation increases too. Burns at 5-year intervals are not frequent enough to promote oak regeneration. Thus, periodic prescribed burns may be used to control competing vegetation and favor advanced oak regeneration.

6. During burning, it is extremely important some residual forest floor be left to protect the site. The key is moisture. The lower portion of the forest floor and mineral soil must be damp when burning is conducted.

7. High-intensity broadcast burns conducted when fuel and moisture conditions are appropriate have little effect on soil erosion and hydrology.

8. Summer broadcast burns accompanied by properly timed felling of residual trees and planting of pine seedlings are currently successful for regenerating mixed pine-hardwood stands. Burning greatly reduces logging residue, thus, helps planting and allows the planted seedlings to successfully compete with sprouts.

9. Postharvest winter burns on cove hardwood sites stimulate the establishment of yellow-poplar from seed stored in the duff. Seed germinates rapidly in the fire-prepared seedbeds.

10. Both low- and high-intensity prescribed fires can benefit several wildlife species by increasing sprouting of nutritious and palatable vegetation.

11. Burning often increases herbaceous forage and associated insect populations, a benefit to certain wildlife species.

12. Although foresters are concerned about stem quality of valuable hardwoods, evidence suggests that low-intensity fires in light fuels have little adverse effect on large trees.

13. Information is needed on how burning influences nutrient cycling and biologic processes in steep terrain.

Air pollution resulting from prescribed burning is a concern, especially in the terrain of the Appalachians. *Population density may also limit the* potential of this valuable management tool. The utmost care in conducting burns in accordance to smoke management guidelines is essential if burning is to become a part of forest management in Appalachian hardwoods.

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